

*SELECTIVE ASSOCIATIONS PRODUCED SOLELY WITH APPETITIVE
CONTINGENCIES: THE STIMULUS-REINFORCER
INTERACTION REVISITED*

STANLEY J. WEISS, LEIGH V. PANLILIO, AND CHARLES W. SCHINDLER

THE AMERICAN UNIVERSITY AND ADDICTION RESEARCH CENTER,
NATIONAL INSTITUTE ON DRUG ABUSE

In studies reporting stimulus-reinforcer interactions in traditional conditioning paradigms, when a tone-light compound was associated with food the light gained stimulus control, but when the compound was paired with shock avoidance the tone gained control. However, the physical nature of the reinforcer-related events (food vs. shock) presented in the presence of the tone-light compound was always confounded with the conditioned hedonic value of the compound's presence relative to its absence. When the compound was paired with shock, its presence was negative relative to its absence (which was shock-free). In contrast, when the compound was paired with food, its presence was positive relative to its absence (which was food-free). The present experiment dealt with this confounding effect by conditioning a tone-light compound to be positive or negative, relative to its absence, solely with food reinforcement. One group of rats received food for responding in the presence of the tone-light compound and no food in its absence. The other group also responded in the presence of the compound, but received food only in its absence. These rats were trained on a chained schedule in which responding in the presence of the tone-light compound produced a terminal link signaled by the absence of the compound; responding ceased in the terminal link because it delayed food delivery. In a test session to assess stimulus control by the elements of the compound, tone and light were presented separately under extinction conditions. Rats that had been exposed to a positive correlation between food and the compound emitted almost double the responses in the presence of the light as in the presence of the tone. In comparison, rats that had been exposed to a negative correlation emitted only two thirds as many responses in the presence of the light as in the presence of the tone. Because this selective association was produced using only food, it appears that the contingencies under which a reinforcer is presented, rather than (or as well as) its physical properties, can generate the selective associations previously attributed to "stimulus-reinforcer interactions." This could mean that regardless of the class of reinforcer that ultimately maintains responding (appetitive or aversive), the contingency-generated hedonic value of the compound stimulus may influence the dominant modality of stimulus control.

Key words: selective associations, biological constraints on learning, stimulus-reinforcer interaction, appetitive-aversive interactions, hedonics, compound stimulus conditioning, lever press, rats

The study of conditioning and learning is concerned with the contingencies that modify behavior and their underlying associative processes. In classical conditioning these modifications are produced by contingencies arranged between a stimulus and an outcome ($S-S^R$). In operant learning they are produced by contingencies arranged between a response and an outcome ($R-S^R$). It has been demonstrated that there are many biological constraints on learning and the associability of various events (Hinde & Stevenson-Hinde, 1973; Seligman & Hager, 1972). Of most immediate interest here is the observation that

when animals are exposed to a compound stimulus that consistently precedes or occasions reinforcement, the strength of conditioning to each element of this compound will be critically affected by the type of reinforcer used (Garcia & Koelling, 1966).

Foree and LoLordo (1973) were among the first to approach the question of selective associations within a traditional learning paradigm. In a discrete-trials operant conditioning procedure, they trained different groups of food-deprived pigeons to depress a foot treadle in the presence of a 5-s compound stimulus consisting of a 440-Hz tone and a red house-light. For one group these treadle presses avoided electric shock, and for the other group they produced access to grain. When the pigeons were effectively avoiding shock or earning food in the compound, the tone and light were presented separately as a test of control by the stimulus elements. After appetitive

This research was supported in part by National Institute of Mental Health Research Grant MH-45545 awarded to the first author. The authors express their appreciation to Richard D. Weissman for his helpful comments on the manuscript. Reprints may be requested from Stanley J. Weiss, Department of Psychology, The American University, Washington, D.C. 20016.

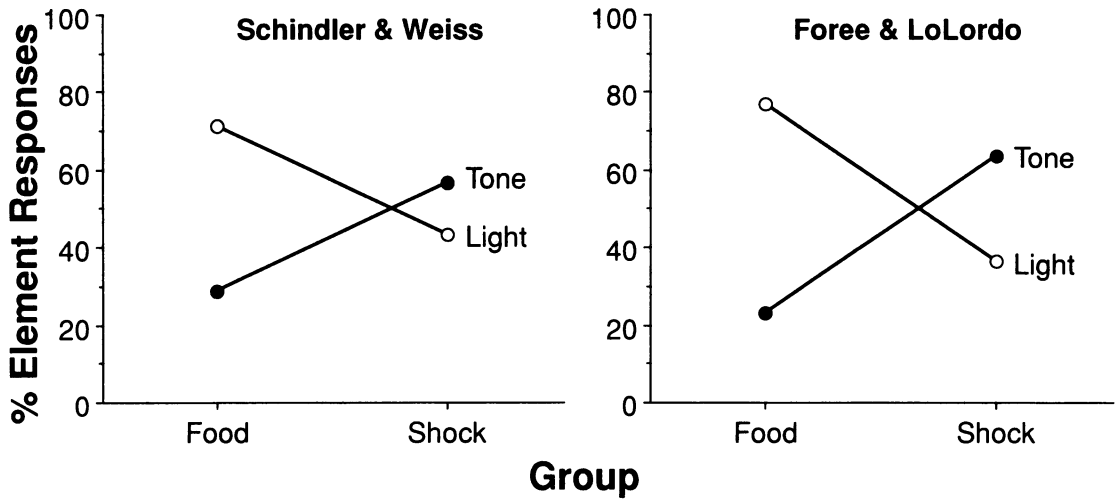


Fig. 1. Left: The percentage of total stimulus-element test responses emitted in tone (filled circles) and in light (open circles) by rats that had been trained by Schindler and Weiss (1982) in tone-plus-light to earn food on a VI schedule or to avoid shock. Right: Same measure for the pigeons of Foree and LoLordo (1973, adapted from their Figure 3). Because different classes of reinforcers, appetitive or aversive, maintained responding in both groups of each study, these profiles have been termed "stimulus-reinforcer interactions."

training, the red light exerted strong control over treadle pressing, and few responses were emitted during the tone. By contrast, after training with shock avoidance in the compound, the tone controlled more treadle pressing than the light did. This "stimulus-reinforcer" interaction is plotted in the right frame of Figure 1.

Schindler and Weiss (1982) expanded the generality of this selective association phenomenon to rats and to free-operant contingencies. In a tone-plus-light (TL) compound one group of rats pressed a lever to produce food on a variable-interval (VI) schedule, and another group pressed to postpone shock on a free-operant avoidance schedule. In the absence of tone and light (\overline{TL}), responding had no scheduled consequences (extinction, EXT). When the subjects were responding at least 10 times as rapidly in TL as in \overline{TL} , a test was administered to assess the degree of control exerted by the tone and light elements. The results of this test are shown in the left frame of Figure 1. Consistent with the findings of Foree and LoLordo (1973), (a) the light gained almost exclusive control of responding when lever pressing was maintained by food, and (b) the tone gained considerable control under the shock-avoidance schedule. A similar selective association was revealed for these two species, even though pigeons are clearly more visual animals than rats are.

It has been confirmed that the stimulus-reinforcer interactions reported by Foree and LoLordo (1973) and Schindler and Weiss (1982) were associative, that is, not a product of sensitization or pseudoconditioning. The stimulus-reinforcer interaction was also revealed (Schindler & Weiss, 1982, Experiment 3) when food as well as shock were presented in the same session, but only one event was associated with the tone-light compound (a control proposed by Rescorla & Holland, 1976). In addition, the stimulus-reinforcer interaction observed by Foree and LoLordo was later replicated in a classical conditioning paradigm that included two truly random control groups that received uncorrelated presentations of the conditioned stimulus and either food or shock (Shapiro, Jacobs, & LoLordo, 1980). The controls revealed no selective associations. Finally, Schindler and Weiss (1985) demonstrated that the stimulus-reinforcer interaction could be blocked if single-stimulus training preceded compound-stimulus training.

We seem to be contacting a basic attentional dynamic here that generalizes across species and experimental conditions. The question that remains, however, is whether this selective association is determined by the physical nature of the reinforcer or some other process operating in these situations. In the studies reporting stimulus-reinforcer interactions in op-

erant (Foree & LoLordo, 1973; Schindler & Weiss, 1982) and classical (Shapiro et al., 1980) situations, the physical nature of the stimulus responsible for reinforcement (food and shock) covaried with what might be considered the conditioned hedonic value of the TL compound. In the experiments by Foree and LoLordo and Schindler and Weiss (described above), when the subjects were working for food during TL they were in a positive condition compared to the nonreinforcement associated with the absence of these stimuli, a condition Holz, Azrin, and Ayllon (1963) used as a punisher. In comparison, when TL was associated with shock avoidance, TL was a negative condition compared to shock-free $\overline{\text{TL}}$ (LoLordo, 1969; Verhave, 1962). The current experiment sought to eliminate this covariation by creating TL compounds of positive and negative hedonic value, that is, stimuli that could serve as conditioned reinforcers or conditioned punishers, respectively, using only appetitive contingencies. To accomplish this, we applied to the analysis of selective associations the generally accepted principle, derived from the study of appetitive-aversive interactions, of the "(affective) equivalence of excitors and inhibitors of contrasted affective value, in terms of both their general excitatory and reinforcing properties and their inhibitory action" (Dickinson & Pearce, 1977, p. 707).

There is substantial evidence that a stimulus signaling the absence of food has many negative properties in common with aversive stimuli such as electric shock (Coughlin, 1972; Leitenberg, 1965). For example, animals will avoid periods of nonreinforcement much as they avoid shock (Daly, 1974), and both shock and nonreinforcement will elicit aggression (Azrin, Hutchinson, & Hake, 1966). Likewise, a stimulus differentially associated with the absence of shock has positive properties that parallel those produced by appetitive reinforcement (LoLordo, 1969; Rescorla, 1969; Weissman & Litner, 1972). What one is therefore concerned with here is not the physical character (e.g., food or shock) of the event ultimately responsible for the association, but rather, functionally, whether the organism is drawn towards (positive) or repelled from (negative) the situation. The organism will work to produce the former and terminate the latter condition.

In the present experiment, lever pressing in TL was ultimately maintained by food in two groups of rats. However, to break the covari-

ation described above between the physical nature of the reinforcer and the conditioned affective value of the TL compound, contingencies were arranged such that, relative to $\overline{\text{TL}}$, TL became hedonically positive (a conditioned appetitive excitator) for one group and hedonically negative (a conditioned appetitive inhibitor) for the other. This latter group was meant to be hedonically comparable to the groups reported by Foree and LoLordo (1973) and Schindler and Weiss (1982), for whom a TL associated with shock avoidance was a conditioned aversive excitator.

In the present experiment, both groups responded in TL and ceased responding in $\overline{\text{TL}}$, just as the food and shock groups presented in Figure 1 did. One group (TL+) earned all their food reinforcers in TL by lever pressing and $\overline{\text{TL}}$ was associated with extinction, like the food group in the Schindler and Weiss (1982) study. In contrast, the other group (TL-) received reinforcers only in $\overline{\text{TL}}$, where responding ceased because it delayed food delivery. The rats in the latter group were on a chained schedule that required pressing in TL to enter the $\overline{\text{TL}}$ component. After the subjects' behavior was brought under stimulus control, they received a stimulus-element test, in which tone and light were presented separately for the first time to determine which modality controlled the response (auditory or visual).

Research with observing behavior presents some of the strongest evidence that TL would acquire opposite hedonic characteristics in the two groups receiving the training summarized above (Dinsmoor, 1983). In typical studies of observing, animals are exposed to a mixed schedule in which the contingencies (usually two) are not correlated with different discriminative stimuli, as they would be in a multiple schedule. However, when the subject emits the observing response, the mixed schedule is briefly changed to a multiple schedule. Therefore, the observing behavior is considered to be a measure of the conditioned reinforcing value of the stimulus it produces. Customarily, only the stimulus associated with the richer reinforcement schedule maintains observing behavior (Auge, 1974; Kendall & Gibson, 1965) whereas a stimulus associated with the lower of two reinforcement frequencies can serve to punish observing behavior (Jwaideh & Mulvaney, 1976). This supports our proposal that TL would become hedonically positive (i.e., a conditioned reinforcer) when it is

positively correlated with food (TL+ group), whereas TL would become hedonically negative (i.e., a conditioned punisher) when it is negatively correlated with food (TL- group).

METHOD

Subjects

The subjects were 10 experimentally naive male Long-Evans hooded rats, approximately 120 days old at the start of the experiment. The rats were maintained at approximately 80% of their roughly 350-g free-feeding weights. They were individually housed in a continuously lighted room with free access to water. Directly after the session they received their rat-diet food ration to supplement the 45-mg P. J. Noyes rat pellets earned during training.

Apparatus

The chamber described by Schindler and Weiss (1982) was used. It measured 21.4 cm by 24.0 cm by 19.5 cm, with the front and rear walls made of aluminum and the two sides and ceiling made of transparent Plexiglas. The floor of the chamber was made up of 16 stainless-steel grids, 0.5 cm in diameter and spaced 1.5 cm apart. On the front wall, 1.0 cm from the left wall and 4.0 cm above the grid floor, was a lever (5.0 cm by 1.0 cm) extending 2.5 cm into the cage. A 2.5-cm downward excursion of the lever, requiring a force of approximately 0.15 N or greater, activated a microswitch, defining the response. Also on the front wall, 0.5 cm from the right wall and 1.0 cm above the grid floor, was a food trough (4.0 cm by 5.0 cm by 2.0 cm). The entire chamber was placed in an Industrial Acoustics Model AC-1 sound-attenuation chamber (58 cm by 40 cm by 35 cm). On the top middle of the back wall of this larger chamber was a partially shielded, continuously illuminated, 25-W houselight providing 1.43 log ft-Lamberts (ft-L) luminance (as measured by an SEI Ilford photometer, directed at the light source). This houselight and an exhaust fan were on throughout every session, and the measurements of the tone and light stimuli were made with the houselight and fan on. A 100-W bulb mounted behind frosted glass in the ceiling of the attenuation chamber, above the training chamber, dimmed by a resistor, provided 0.55 log ft-L during the compound stimulus with the

photometer directed at the front wall. (The illumination of the houselight was too weak to activate the photometer when directed at this wall.) With the exhaust fan running, the noise level was 75 dB in the experimental chamber (as measured by a General Radio 1565-A sound level meter, Scale C, with the microphone centered on the front wall). A 10-cm speaker was mounted on the left wall of the larger chamber. The auditory stimulus was a 2000-Hz tone at 79 db. (This was the low intensity tone-light compound employed by Schindler & Weiss, 1982.) Solid-state programming equipment in an adjacent room scheduled all experimental events.

Procedure

After random assignment to a group, each rat was trained to eat from the food magazine. Food pellets were presented response independently, following the sound of the feeder, in the stimulus condition in which the rat would later receive food on its training schedule. Thus, the 5 rats in the TL+ group were trained in the TL compound, and the 5 rats in the TL- group were trained in TL. Next, lever pressing was shaped by the method of successive approximations.

Chain VI DRO (TL-) group. For this group, the shaping procedure involved a chained (chain) schedule with a continuous reinforcement (CRF) link leading to a differential-reinforcement-of-other-behavior (DRO) 2-s link. On this schedule, a lever press during TL immediately turned off the compound, and a food pellet was delivered after the rat had been in TL for 2 s without pressing the lever. TL was again presented 10 s following food. For the first two training sessions, only one pellet was delivered per TL component. Thereafter, DRO component lengths within a session ranged from several seconds beyond the DRO value to approximately four times that value, with a mean approximately equal to twice the DRO value. Thus, from one to four pellets per component could be delivered if the DRO requirement was met. Following a TL component, TL came back on with a VI schedule in effect that could, as the reinforcer for lever pressing, return the rat to TL. As a subject revealed appropriate stimulus control, the VI schedule was gradually increased through VI 15, 22, 30, 45, and finally to 60 s. The DRO value was also gradually increased, and

was 30 s on the final schedule. Thus, a pellet was delivered every 30 s in the absence of responding, and each response reset a 30-s timer. The 30-s value was chosen because it produced, overall, response rates in TL comparable to those produced by the VI 45-s schedule of the TL+ group described below. When $\overline{\text{TL}}$ ended, any accumulated DRO time was lost, but that was not the case for the VI 45-s schedule in the TL component of the TL+ group. For that group, in any TL component the VI timer continued from the point at which it stopped when the previous TL component ended.

On the VI schedules, intervals were sequenced such that any interval was likely to follow any other interval with roughly equal probability. The limit of any VI was 2 s to three times the mean. To increase rates in TL, early in training a variable-ratio (VR) 12 was substituted for the VI schedule for several sessions. Sessions were ended after approximately 2 hr had elapsed or 130 pellets had been delivered, whichever occurred first. A rat was trained on its final baseline schedule, chain VI 60 s DRO 30 s, until it attained a TL: $\overline{\text{TL}}$ discrimination ratio of at least 10:1 for 3 consecutive days with no apparent trend. It was then administered the stimulus-element test described below.

Mult VI EXT (TL+) group. After lever pressing was shaped in TL, rats in this group were given two sessions of VI 15-s training in that stimulus. Subsequent sessions consisted of alternating TL and $\overline{\text{TL}}$ components. A VI food schedule operated in TL, while no reinforcers were available in $\overline{\text{TL}}$. On this multiple (mult) VI EXT schedule, the VI schedules were gradually increased, as they were for the chain VI DRO subjects, but only up to 45 s. To keep contingency exposure as comparable as possible across groups, a VR 12 schedule was instituted in TL with this group for several sessions at about the same point in training as it was applied to the chain VI DRO group. The EXT component varied in duration from 20 to 60 s, but after about 10 multiple-schedule sessions a correction procedure was added such that a response in $\overline{\text{TL}}$ would reset the clock timing the EXT component back to its full duration. On the final baseline, mult VI 45 s EXT, VI component lengths in this group varied within the limits of 45 to 145 s, a range similar to that of the DRO components of the

chain VI 60-s DRO 30-s schedule. The range of component lengths in $\overline{\text{TL}}$ was set to keep TL and $\overline{\text{TL}}$ lengths roughly comparable during each session. Session length was determined as it was for the TL- group. When these rats satisfied the same discrimination and stability criteria described above, they were tested.

Stimulus-element test. After a warm-up period on the baseline schedule in which 25 pellets were earned, testing began. The test, performed in extinction, consisted of 12 block-randomized replications of 60-s presentations of tone, light, and TL. Each block included one presentation each of tone, light, and TL, with 60 s of $\overline{\text{TL}}$ separating these presentations. A representative test block might have consisted of tone, $\overline{\text{TL}}$, TL, $\overline{\text{TL}}$, light, $\overline{\text{TL}}$. Each test was arranged as four Latin squares, with three blocks in each Latin square. Each test sequence was slightly different and was randomly assigned to a subject.

RESULTS AND DISCUSSION

Baseline Behavior

Table 1 presents baseline data for the two groups averaged over the 10 sessions prior to testing. Their lever-pressing behavior was comparable at the termination of training. Mean response rates in TL were within 0.1 responses per minute across groups, and those in $\overline{\text{TL}}$ were within 0.7 of each other. The time the chain VI DRO group spent eating in $\overline{\text{TL}}$, as well as the DRO contingency, was probably responsible for its rate in this stimulus being somewhat lower than that of the mult VI EXT group. Total hours of training, as well as the percentage of the training sessions spent in TL, were comparable for the two groups. To produce comparable response rates in TL in the two groups, the chain VI DRO group received 25% more pellets per minute in $\overline{\text{TL}}$ than the mult VI EXT group received in TL. This difference is of little consequence to the present manipulation because neither group received any pellets in their other schedule component. That is, the food discrimination was all versus none for both groups.

Figure 2 presents cumulative records generated by each rat during the pretest warm-up period. Records are ordered from highest to lowest with respect to baseline TL response

Table 1

Baseline training comparisons: Hours of training and percentage of time spent in the tone-light stimulus compound during training, rate of reinforcement (food pellets per minute within the schedule component in which food was presented), and rate of lever pressing (responses per minute) in the presence (TL) and absence ($\overline{\text{TL}}$) of the stimulus compound during the final 10 baseline sessions. Also shown are group means and *t* tests with associated probabilities to assess the statistical significance of the differences between groups.

Subject	Hours of training	% of time in TL	Pellets per minute	Responses per minute in TL	Responses per minute in $\overline{\text{TL}}$
Mult VI EXT group					
54	26.2	47.7	1.10	11.7	1.3
59	23.5	52.0	1.33	14.5	2.0
81	23.3	50.3	1.20	13.6	1.8
87	37.5	39.8	1.31	19.1	1.7
91	26.8	54.0	1.10	6.2	0.9
<i>M</i>	27.5	48.8	1.21	13.0	1.5
Chain VI DRO group					
55	22.2	50.8	1.44	15.9	0.7
60	25.2	49.9	1.43	26.5	2.1
80	27.9	27.9	1.32	4.9	0.5
84	21.2	21.2	1.50	9.2	0.3
89	22.3	22.3	1.80	8.0	0.2
<i>M</i>	23.8	34.2	1.50	12.9	0.8
<i>t</i> tests					
<i>t</i> (8)	1.284	2.089	-3.061	0.027	1.961
<i>p</i>	.23	.07	.02	.98	.08

rates presented in Table 1. Arranged in this manner, the records from subjects of the two groups are intermixed. In addition, the groups were not distinguishable by their patterns of responding in TL and $\overline{\text{TL}}$.

From the training comparisons considered above, it seems safe to conclude that the operant behavior of the mult VI EXT and chain VI DRO groups (our dependent variable on the stimulus-element test) was comparable prior to testing. The rats pressed the lever in TL and essentially ceased in $\overline{\text{TL}}$, and these response patterns were maintained by food-based contingencies in both groups. However, it would be naive to assume that this comparability can be taken as an indication that the two contingencies did not produce behavioral differences across groups. For example, primary reinforcement was earned under a VI schedule in one group and a DRO schedule

in the other. Nevertheless, this should have little effect on our independent variable, because the value of predictive stimuli as reinforcers is determined primarily by the value of events predicted rather than response requirements (Dinsmoor, Bowe, Green, & Hansen, 1988). As explained earlier, research on observing behavior supports the proposal that in the mult VI EXT group, TL would be a conditioned reinforcer (appetitive excitator), whereas in the chain VI DRO group, TL would be a conditioned punisher (appetitive inhibitor).

Stimulus-Element Test

Rates controlled by tone, light, TL, and $\overline{\text{TL}}$ in individual subjects for the entire test are presented in Table 2. All rats in the chain VI DRO group emitted clearly more responses in the tone than in the light test element, but no

Fig. 2. Cumulative records of each subject on its baseline training schedule just prior to the stimulus-element test, presented in order of decreasing response rate. The subject's baseline schedule, chain VI DRO or mult VI EXT, is indicated to the right of each record. The pen in the upper register indicates a tone-plus-light (TL) component. During the absence of TL, the pen was in its lower register. Upward or downward slash marks indicate food reinforcements.

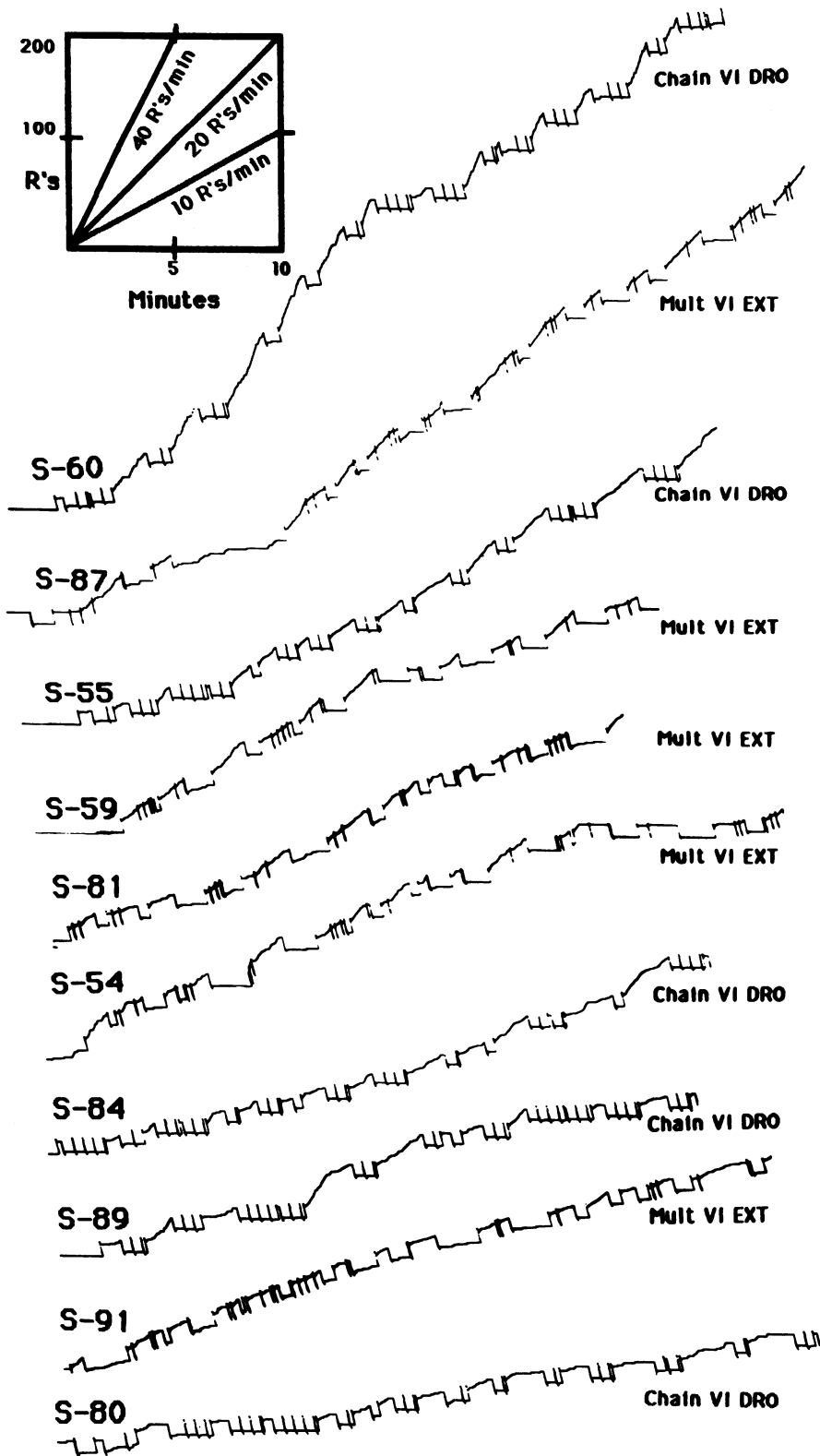


Table 2

Test session: Rates of lever pressing (responses per minute) in the presence of the tone and the light stimulus elements, in the tone-light compound (TL), and in the absence of the compound (\overline{TL}). Results from the chain VI DRO group are shown twice, once based on all of the data from the test session and once based only on tone, light, and TL periods preceded by \overline{TL} periods without responding during the final 20 s.

Sub- ject	Tone	Light	TL	\overline{TL}
Mult VI EXT group				
54	1.7	2.3	8.6	0.0
59	1.1	6.0	11.7	0.1
81	1.7	1.7	6.9	0.0
87	2.0	8.2	16.2	0.3
91	1.1	1.0	4.5	0.2
<i>M</i>	1.5	3.9	6.7	0.1
Chain VI DRO group				
55	9.9	6.7	9.0	3.9
60	16.7	8.7	15.7	11.9
80	2.5	1.4	1.9	1.2
84	5.6	4.4	4.5	4.0
89	3.5	2.7	4.3	1.6
<i>M</i>	7.6	4.8	7.1	4.5
Chain VI DRO (\overline{TL} criterion)				
55	8.3 (9) ^a	2.2 (4) ^a	9.4 (9) ^a	0 (22) ^b
60	6.8 (6)	3.0 (8)	11.3 (9)	0 (23)
80	2.2 (10)	1.4 (12)	1.8 (10)	0 (32)
84	5.0 (10)	2.7 (7)	3.7 (9)	0 (26)
89	3.8 (9)	1.7 (8)	3.7 (9)	0 (26)
<i>M</i>	5.2 (8.8)	2.2 (7.8)	6.0 (9.2)	0 (25.8)

^a Figures in parentheses in these columns indicate number of test replications, out of 12, included in the rate determination.

^b Figures in parentheses in this column indicate number of TL periods, out of 36, during which no responses occurred during the final 20 s.

rat in the mult VI EXT group did this. Three rats in the mult VI EXT group emitted clearly more responses in the light than in the tone, and 2 rats (81 and 91) from this group responded comparably to the elements.

The left frame of Figure 3 presents the interaction profile representing stimulus control exerted by the tone and light elements over the groups. On the average, rats in the chain VI DRO group emitted 40% of their element responses in the presence of the light $[(100 \times L)/(T + L)]$, whereas the mult VI EXT group emitted 65% of their element responses in the light. This difference is statistically significant, $t(8) = 3.09$, $p < .02$. The distribution of element responses for the chain VI DRO group, for whom no food was received in TL, resembles that of animals that avoided shock during

TL in the Schindler and Weiss (1982) study. This can be seen by comparing Figure 3A with the left frame of Figure 1.

Frames A and B of Figure 4 present the test responses to tone, light, and TL as a percentage of the summed responses to these stimuli for subjects of the two groups. The difference in element control has already been seen in the interaction profile of Figure 3. These frames of Figure 4 reveal that the groups also differed with respect to control exerted by the TL compound, relative to that of the elements, in testing. The TL test stimulus controlled 65% of combined compound and element test responses for the mult VI EXT group, whereas TL controlled 36% of these combined responses for the chain VI DRO group, a statistically significant difference, $t(8) = 12.82$, $p < .01$. These mean distributions are clearly representative of the individuals in each group. A similar effect was also reported by Schindler and Weiss (1982) for their group trained on mult VI EXT. This effect might be due to the fact that for animals trained on mult VI EXT, in TL the operant ($R-S^R$) and respondent ($S-S^R$) contingencies are both excitatory. In contrast, for the chain VI DRO group, in TL response rate was increasing (excitatory) while reinforcement rate was decreasing (inhibitory), placing these contingencies in conflict (see Weiss, 1976, 1978; Weiss & Van Ost, 1974; Weiss & Weissman, 1992).

In training, both groups had negligible response rates in \overline{TL} that were within 0.7 responses per minute of each other, as shown in Table 1 and Figure 2. However, Table 2 shows that the chain VI DRO group emitted more responses in the \overline{TL} periods separating tone, light, and TL test-stimulus conditions than the mult VI EXT group, a difference that approached statistical significance, $t(8) = 2.28$, $p = .052$. A functional analysis of the transition from training to testing for each group might help explain this difference in the capacity of \overline{TL} to maintain its stimulus control in testing. For the mult VI EXT group, all components switched independently of a rat's behavior in training and testing, and TL was associated with the same condition (extinction) in training and testing. For the chain VI DRO group, in comparison, there were more dramatic changes from training to testing. For example, on the chained schedule, in training a \overline{TL} component was always produced by a lever press

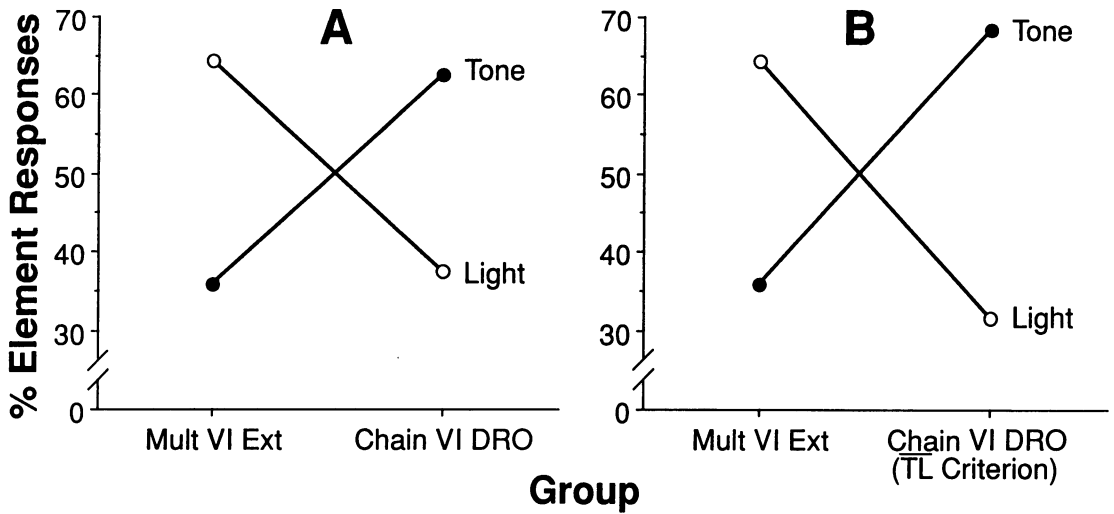


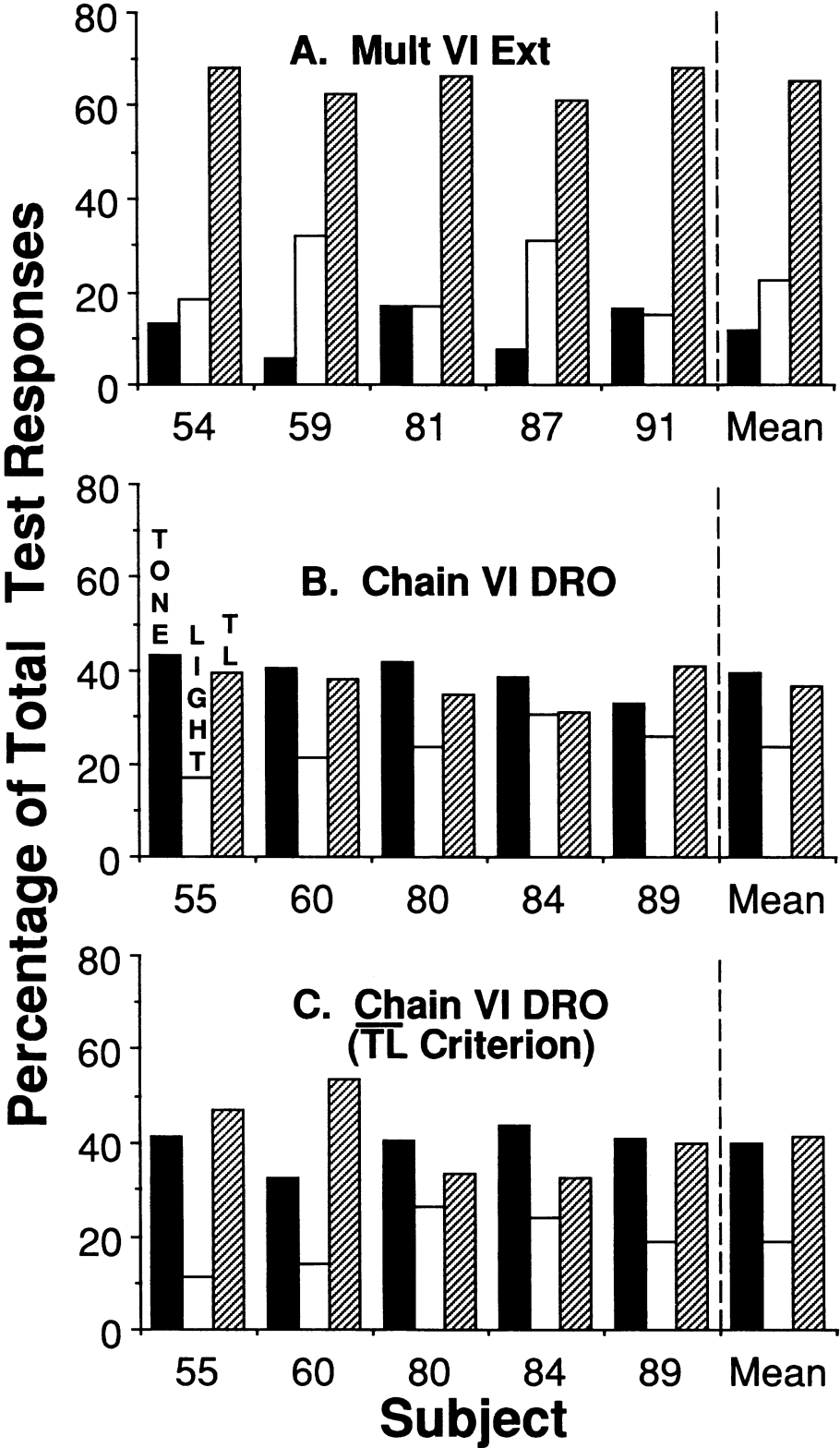
Fig. 3. The percentage of stimulus-element responses to the tone (filled circles) and the light (open circles) by the mult VI EXT group and by the chain VI DRO group in testing. The left frame (A) presents the profile generated when all the chain VI DRO group test data were used. The right frame (B) presents the profile produced when only the TL criterion data from this group were used (see text for details).

in TL that satisfied the VI schedule, whereas in testing the components had to switch automatically to maintain temporal comparability of components across groups. In addition, in training on the chained schedule, reinforcement was always presented after 30 s without a response in $\overline{\text{TL}}$, whereas reinforcement was not presented in testing. Either of these training-to-test differences could have interfered with $\overline{\text{TL}}$'s capacity to inhibit lever pressing completely in the chain VI DRO subjects (i.e., disinhibition might have occurred). Nevertheless, the overall pattern of this group's test results clearly supports the conclusion that the tone element of the TL compound was controlling a greater increase in lever pressing than was the light element. The majority of the chain VI DRO subjects had comparable test response rates in the light element and $\overline{\text{TL}}$, but they *all* responded at higher rates in tone than in $\overline{\text{TL}}$ or in light. This is the opposite of the element control revealed in the mult VI EXT group.

One could, however, argue that the test results might have been influenced by the fact that rats with multiple-schedule training consistently entered the tone, light, and TL periods from a state of nonresponding, whereas that was not necessarily the case for rats trained with the chained schedule (see $\overline{\text{TL}}$ column in Table 2). To deal with this concern, the test

results of the chain VI DRO group were reanalyzed to determine the control during tone, light, and TL when the $\overline{\text{TL}}$ rates immediately preceding these test components were comparable to those of the multiple-schedule animals. This was accomplished by using the data from a tone, light, or TL test period *only* when no responses were emitted in the final 20 s of the immediately preceding 60-s $\overline{\text{TL}}$ period. That produced the "TL criterion" chain VI DRO group results presented in the final section of Table 2 and Panel C of Figure 4, which include approximately 70% of the test for these subjects.

Comparing test profiles for individual subjects between the lower two sections of Table 2, or between Frames B and C of Figure 4, shows that using only the $\overline{\text{TL}}$ criterion data left the overall pattern of the test results essentially unchanged. Again, rates in tone were higher than those in light for all chained-schedule animals. Applying the $\overline{\text{TL}}$ criterion to the chain group's results decreased overall rates to light by close to 55%, whereas those to tone decreased by only 32%, amplifying the superiority of tone-element control. With the criterion data, the tone controlled 69% of the element responses, compared to only 60% with the total test data, a difference that approached statistical significance, $t(4) = 2.17$, $.1 > p > .05$. In the interaction profile presented in



Frame B of Figure 4, the percentage of element responses controlled by the light is again greater for the multiple group than for the chain group (65% vs. 31%, a statistically significant difference, $t(8) = 3.97$, $p < .01$), just as it was in Frame A.

These comparisons between the \overline{TL} criterion data and the total test data of the chained schedule animals show that the difference in element control across groups was not due to differences in \overline{TL} rates immediately preceding tone and light test components. Rather, differences in element control can be attributed confidently to the influence of the characteristics of these appetitive training contingencies on selective associations. Therefore, the present study was successful in demonstrating that the kind of selective-association interaction profiles that were previously attributed to differential effects of food versus shock can be produced using only food-related contingencies.

An explanation of the profiles reported in the present experiment that might also be applied to those studies producing "stimulus-reinforcer" interactions with food and shock (e.g., Foree & LoLordo, 1973; Schindler & Weiss, 1982) would define "reinforcer" with respect to the comparability of excitors and inhibitors of contrasted affective value rather than the physical characteristics of the reinforcer per se. According to this formulation, explained in the introduction to this paper, a conditioned aversive excitor such as a TL positively associated with shock, which produces auditory control, would be considered hedonically comparable to a conditioned appetitive inhibitor such as a TL negatively associated with food, as in the chain VI DRO group. This is supported by observing-response studies showing that a condition like the TL component of the chain schedule in the present experiment, in which tone control was superior, has aversive properties expected of a conditioned appetitive inhibitor (Mulvaney,

Dinsmoor, Jwaideh, & Hughes, 1974; Jwaideh & Mulvaney, 1976).

The findings reported by Jacobs and LoLordo (1977, 1980), who compared the effectiveness of auditory and visual warning and safety signals, also reveal the limitations of a stimulus-reinforcer interaction interpretation of selective associations. In both of their experiments, rats were initially trained to respond to avoid shock on a free-operant baseline. Jacobs and LoLordo (1980) paired auditory and visual stimuli with the onset or termination of shock, making them warning and safety signals, respectively. Jacobs and LoLordo (1977) created the same stimulus-shock relations using a discrete-trials avoidance schedule in which a new response terminated the warning stimulus and produced the safety stimulus. In both experiments, the rats were then returned to the free-operant avoidance baseline, with the auditory and visual stimuli presented in a transfer-of-control procedure. As a warning stimulus, only the onset of noise increased avoidance responding. However, the onset of light, the offset of light, and the offset of noise (but *not* the onset of noise) decreased avoidance responding when they had been paired with safety from shock. This indicated that when paired with shock, only the auditory stimulus was effective as a conditioned aversive excitor. In comparison, when associated with safety, only the nonauditory stimuli were effective as conditioned aversive inhibitors. The stimuli were differentially effective when placed in different relations to the same event, shock. This is similar to the way in which they were differentially effective when placed in different relations to food in the current experiment.

Foree and LoLordo (1975, Experiment 1) trained pigeons under a schedule that possessed some similarities to the chained schedule of the present experiment, but the outcome of their stimulus-element test was different. After training pigeons to eat from a grain hopper

←

Fig. 4. The percentage of test responses emitted in the tone, light, and tone-plus-light (TL) compound by the individual subjects of the mult VI EXT and chain VI DRO groups. The response outputs of each subject to these test conditions were converted to a percentage of that subject's total test responses summed over tone, light, and TL conditions. The means at the extreme right of each frame represent percentages averaged over subjects within a group. Frames A and B present the complete test data for the mult VI EXT and chain VI DRO groups, respectively. Frame C presents the \overline{TL} criterion data for the chain VI DRO group (see text for details).

when it was lighted, they taught them to peck a lighted key with an autoshaping procedure. Thereafter, pecking was reinforced with food on a VI 30-s schedule. Subsequently, a red light-tone compound served as a 10-s warning stimulus for extinction, and a treadle press would avoid, or once commenced, escape, the extinction period. In this experiment, as well as their Experiment 2, in which the compound signaled punishment for pecking, the treadle press came under mainly visual control. This led the authors to conclude that, with birds, control is primarily visual when there is food reinforcement, even when aversive stimuli are also present (cf. Shettleworth, 1972). Although the influence of food reinforcement might be operating with these essentially visual animals, it is entirely possible that Foree and LoLordo, in addition, created a bias towards visual control. They could have done this by (a) initially signaling grain in the hopper with a feeder light, (b) autoshaping with the key illuminated by white light for 8 s prior to 5-s access to grain, and (c) maintaining key pecking for food under visual control over the entire session. Performing their experiment without these potential visual biases, with an auditory signal for the hopper, and, perhaps, with food-maintained pecking of an unlighted key would be revealing. In addition, it should be noted that selective associations involving a tone and light may be more constrained in pigeons than in rats. They could not be reversed by a blocking procedure (Kamin, 1969) in pigeons (LoLordo, Jacobs, & Foree, 1982), but could be blocked in rats (Schindler & Weiss, 1985).

CONCLUSION

The present experiment was formulated on the basis of the confounding effect of the physical nature of the reinforcer-related events (food vs. shock) presented in TL and the resulting affective value that would have been conditioned to the TL compound in the Foree and LoLordo (1973), Shapiro *et al.* (1980), and Schindler and Weiss (1982) studies of selective association. The present experiment broke this covariation by making TL a negative condition for the chain VI DRO group with a food-related contingency, rather than with a shock-related contingency as in the previous studies. The chain VI DRO animals appeared to reveal their preference for TL over TL by continually responding in the latter condition to

produce the former. Unfortunately, this measure could be contaminated by the fact that "the same response is allowed to produce both the conditioned reinforcer and, after a delay, the primary reinforcer with which that stimulus is associated" (Dinsmoor, 1983, p. 696). However, the literature on observing behavior described earlier has shown, with a measure not open to this criticism, that stimuli negatively correlated with food—such as the TL for the chain VI DRO group—become aversive.

The stimulus-element test of the chain VI DRO group produced a selective-association interaction profile similar to those reported when compound control by food and shock was compared by Schindler and Weiss (1982). This suggests that the dynamics underlying selective associations might be better understood in terms of "the equivalence of excitors and inhibitors of contrasted affective value" (Dickinson & Pearce, 1977, p. 707). The Jacobs and LoLordo (1977, 1980) experiments showing the formation of selective associations to warning and safety signals, both maintained by their relationship to the same reinforcer (shock), are also consistent with this approach.

At this stage in our investigations of the factors responsible for selective associations, the suggestion that the relative hedonic value of TL (as measured by preference or observing behavior) might be a determinant of stimulus control in these situations should be viewed as a catalyst for additional research in this area rather than as a proven dynamic. If confirmed with additional research, despite the risks of affirming the consequent (Sidman, 1960), it should encourage us to look for biological constraints (influences) on learning at a more general level of processing than heretofore investigated.

The present results suggest that selective associations might be a product of a conditioned psychological hedonic state. If this turns out to be the case, it could mean that the same variables involved in fundamental psychological processes, such as choice behavior in general, conditioned preference, and appetitive-aversive interactions (deVilliers, 1977; Dickinson & Dearing, 1979; Herrnstein, 1970; Weiss & Schindler, 1989), might also contribute to selective associations. That exciting integration would relate selective associations to general process learning theory (Domjan, 1983;

Domjan & Galef, 1983). At a minimum, however, the basic finding of the present experiment, that selective associations can be produced by manipulating contingencies involving solely food, requires that this phenomenon be viewed from a broader perspective. The procedures used in producing what have up to now been called "stimulus-reinforcer interactions" appear to be only one way of producing this selectivity in associability, or possibly a special instance of a more fundamental process. In either case, the present findings should increase our appreciation of the power of contingencies themselves, independently of the physical nature of the primary reinforcer, in influencing stimulus selectivity. They should also sensitize us to the fact that there is much more to learn about selective associations.

REFERENCES

- Auge, R. J. (1974). Context, observing behavior, and conditioned reinforcement. *Journal of the Experimental Analysis of Behavior*, **22**, 525-533.
- Azrin, N. H., Hutchinson, R. R., & Hake, D. F. (1966). Extinction induced aggression. *Journal of the Experimental Analysis of Behavior*, **9**, 191-204.
- Coughlin, R. C. (1972). The aversive properties of withdrawing positive reinforcement: A review of the recent literature. *Psychological Record*, **22**, 333-354.
- Daly, H. B. (1974). Reinforcing properties of escape from frustration aroused in various learning situations. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 8, pp. 187-231). New York: Academic Press.
- de Villiers, P. (1977). Choice in concurrent schedules and a quantitative formulation of the law of effect. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior* (pp. 233-287). Englewood Cliffs, NJ: Prentice-Hall.
- Dickinson, A., & Dearing, M. F. (1979). Appetitive-aversive interactions and inhibitory processes. In A. Dickinson & R. A. Boakes (Eds.), *Mechanisms of learning and motivation: A memorial volume to Jerzy Konorski* (pp. 203-232). Hillsdale, NJ: Erlbaum.
- Dickinson, A., & Pearce, J. M. (1977). Inhibitory interactions between appetitive and aversive stimuli. *Psychological Bulletin*, **84**, 690-711.
- Dinsmoor, J. A. (1983). Observing and conditioned reinforcement. *Behavior and Brain Sciences*, **6**, 693-728.
- Dinsmoor, J. A., Bowe, C. A., Green, L., & Hansen, J. (1988). Information on response requirements compared with information on food density as a reinforcer of observing in pigeons. *Journal of the Experimental Analysis of Behavior*, **49**, 229-237.
- Domjan, M. (1983). Biological constraints on instrumental and classical conditioning: Implications for general process theory. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 17, pp. 215-277). New York: Academic Press.
- Domjan, M., & Galef, B. G., Jr. (1983). Biological constraints on instrumental and classical conditioning: Retrospect and prospect. *Animal Learning & Behavior*, **11**, 151-161.
- Forsee, D. D., & LoLordo, V. M. (1973). Attention in the pigeon: Differential effects of food-getting versus shock-avoidance procedures. *Journal of Comparative and Physiological Psychology*, **85**, 551-558.
- Forsee, D. D., & LoLordo, V. M. (1975). Stimulus-reinforcer interactions in the pigeon: The role of electric shock and the avoidance contingency. *Journal of Experimental Psychology: Animal Behavior Processes*, **114**, 39-46.
- Garcia, J., & Koelling, R. A. (1966). Relation of cue to consequence in avoidance learning. *Psychonomic Science*, **4**, 123-124.
- Herrnstein, R. J. (1970). On the law of effect. *Journal of the Experimental Analysis of Behavior*, **13**, 243-266.
- Hinde, R. A., & Stevenson-Hinde, J. (Eds.). (1973). *Constraints on learning*. New York: Academic Press.
- Holz, W. C., Azrin, N. H., & Ayllon, T. (1963). Elimination of behavior of mental patients by response-produced extinction. *Journal of the Experimental Analysis of Behavior*, **6**, 407-412.
- Jacobs, W. J., & LoLordo, V. M. (1977). The sensory basis of avoidance responding in the rat: Relative dominance of auditory or visual warning signals and safety signals. *Learning and Motivation*, **8**, 448-466.
- Jacobs, W. J., & LoLordo, V. M. (1980). Constraints on Pavlovian aversive conditioning: Implications for avoidance learning in the rat. *Learning and Motivation*, **11**, 427-455.
- Jwaideh, A. R., & Mulvaney, D. E. (1976). Punishment of observing by a stimulus associated with the lower of two reinforcement densities. *Learning and Motivation*, **7**, 211-222.
- Kamin, L. J. (1969). Predictability, surprise, attention, and conditioning. In B. A. Campbell & R. M. Church (Eds.), *Punishment and aversive behavior* (pp. 279-296). New York: Appleton-Century-Crofts.
- Kendall, S. B., & Gibson, D. A. (1965). Effect of discriminative stimulus removal on observing behavior. *Psychological Record*, **15**, 545-551.
- Leitenberg, H. (1965). Is time out from positive reinforcement an aversive event? A review of the experimental evidence. *Psychological Bulletin*, **64**, 428-441.
- LoLordo, V. M. (1969). Positive conditioned reinforcement from aversive situations. *Psychological Bulletin*, **72**, 193-203.
- LoLordo, V. M., Jacobs, J. J., & Forsee, D. D. (1982). Failure to block control by a relevant stimulus. *Animal Learning & Behavior*, **10**, 183-193.
- Mulvaney, D. E., Dinsmoor, J. A., Jwaideh, A. R., & Hughes, L. H. (1974). Punishment of observing by the negative discriminative stimulus. *Journal of the Experimental Analysis of Behavior*, **21**, 37-44.
- Rescorla, R. A. (1969). Establishment of a positive reinforcer through contrast with shock. *Journal of Comparative and Physiological Psychology*, **67**, 260-263.
- Rescorla, R. A., & Holland, P. C. (1976). Some behavioral approaches to the study of learning. In M. R. Rosenzweig & E. L. Bennett (Eds.), *Neural mechanisms of learning and memory* (pp. 165-192). Cambridge, MA: MIT Press.
- Schindler, C. W., & Weiss, S. J. (1982). The influence of positive and negative reinforcement on selective attention in the rat. *Learning and Motivation*, **13**, 304-323.

- Schindler, C. W., & Weiss, S. J. (1985). Modification of a stimulus-reinforcer interaction by blocking. *Behavioural Processes*, *11*, 123-130.
- Seligman, M. E. P., & Hager, J. L. (1972). *Biological boundaries of learning*. New York: Appleton-Century-Crofts.
- Shapiro, K. L., Jacobs, W. J., & LoLordo, V. M. (1980). Stimulus-reinforcer interactions in Pavlovian conditioning of pigeons: Implications for selective associates. *Animal Learning & Behavior*, *8*, 586-594.
- Shettleworth, S. J. (1972). Stimulus relevance in the control of drinking and conditioned fear responses in domestic chicks (*Gallus gallus*). *Journal of Comparative and Physiological Psychology*, *80*, 175-198.
- Sidman, M. (1960). *Tactics of scientific research*. New York: Basic Books.
- Verhave, T. (1962). The functional properties of time out from an avoidance schedule. *Journal of the Experimental Analysis of Behavior*, *5*, 391-422.
- Weiss, S. J. (1976). Stimulus control of free operant avoidance: The contribution of response rate and incentive relations between multiple schedule components. *Learning and Motivation*, *7*, 477-516.
- Weiss, S. J. (1978). Discriminated response and incentive processes in operant conditioning: A two-factor model of stimulus control. *Journal of the Experimental Analysis of Behavior*, *30*, 361-381.
- Weiss, S. J., & Schindler, C. W. (1989). Integrating control generated by positive and negative reinforcement: Appetitive-aversive interactions. *Animal Learning & Behavior*, *17*, 433-446.
- Weiss, S. J., & Van Ost, S. L. (1974). Response discriminative and reinforcement factors in the stimulus control of performance on multiple and chained schedules of positive reinforcement. *Learning and Motivation*, *5*, 459-472.
- Weiss, S. J., & Weissman, R. D. (1992). Generalization peak shift for autoshaped and operant key pecks. *Journal of the Experimental Analysis of Behavior*, *57*, 127-143.
- Weissman, R. G., & Litner, J. S. (1972). The role of Pavlovian events in avoidance training. In R. A. Boakes & M. S. Halliday (Eds.), *Inhibition and learning* (pp. 253-270). London: Academic Press.

Received March 30, 1992

Final acceptance November 6, 1992